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Study of Optical Character of Nano-antenna

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Abstract: *In this research paper metallic optical nano-antenna has been presented. The characteristics of optical nano-antenna and its dependence on the geometry and materials have been studied. Some special types of nano-antennas have been presented and their potential applications have also been described. If the size of an antenna is shrunk to the nano-scale, it could have potential applications in Nano-photonics. The Nano antennas can also be used to generate electronic surface waves known as "surface plasmons". This is done by confining electromagnetic waves between metallic nano-structure and a dielectric.*

Keywords: *Nano-antenna, Surface Plasmon, Photonics, Metal-Oxide-Meta (MOM)*

I. INTRODUCTION

Conventional antennas are widely used to transmit Radio or TV signals. They can be used at optical frequencies, if they are shrunk to the nano-scale, which could have potential applications in nano-photonics. The nano- antennas can also be used to generate electronic surface waves known as "surface plasmons. This is done by confining electromagnetic waves – typically at the interface between metallic nanostructures and a dielectric material. Each dimension of the nano boundary should be approximately smaller than half the wavelength of incident light. Recently researchers have been able to design such a nano-antenna which could collect and focus light waves so that it could be used to detect specific particle and atom.

II. The Concept Of An Optical Antenna

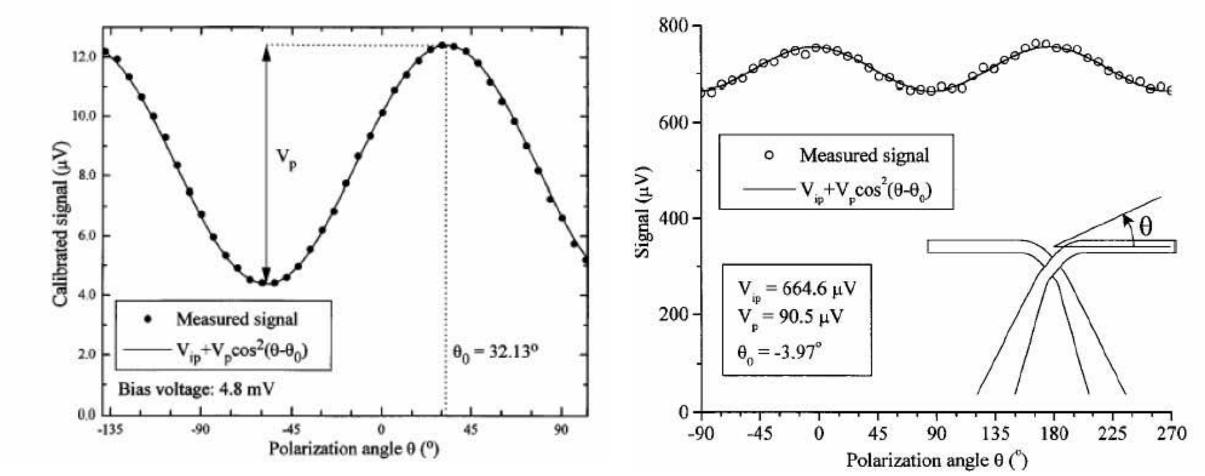
The optical antennas stand for a new class of light detector, or as a metallic structure that couples electromagnetic radiation at optical frequencies. The behavior of metal at optical frequencies is very different with respect to their counterparts at radio-band and microwave-band. Optical antennas working in the infrared region, even in the far infrared band, do not need auxiliary cooling subsystems. This advantage is very much appreciated when comparing optical antennas with the conventional detection technologies that use sophisticated cryogenic equipment to reduce the noise of the detectors. Some of these properties are intrinsically related with the antenna design and cannot be performed by semiconductor detectors. The high frequency of the optical radiation and the need to extract electric signals manageable by post-processing electronics makes possible a phase detection of the incoming radiation. So far there have not been positive results reporting the emission of optical radiation by optical antennas structures. Different designs of optical antennas have been proposed mimicking some of the proved layouts already working in the microwave and radio electric design. In figure 1 three possible designs of optical antennas structures have been shown which have positive results reporting the emission of optical radiation. We can see a dipole antenna (left), an asymmetric spiral antenna (center), and a patch antenna on a moving bridge (right). The physical mechanism for the transducer is a micro-bolometer for the left and right antennas, and a MOM diode for the central one.

Fig. (1): Different types of optical antennas written by electron beam lithography on Si wafers.

III. Polarization Sensitivity and Tunning

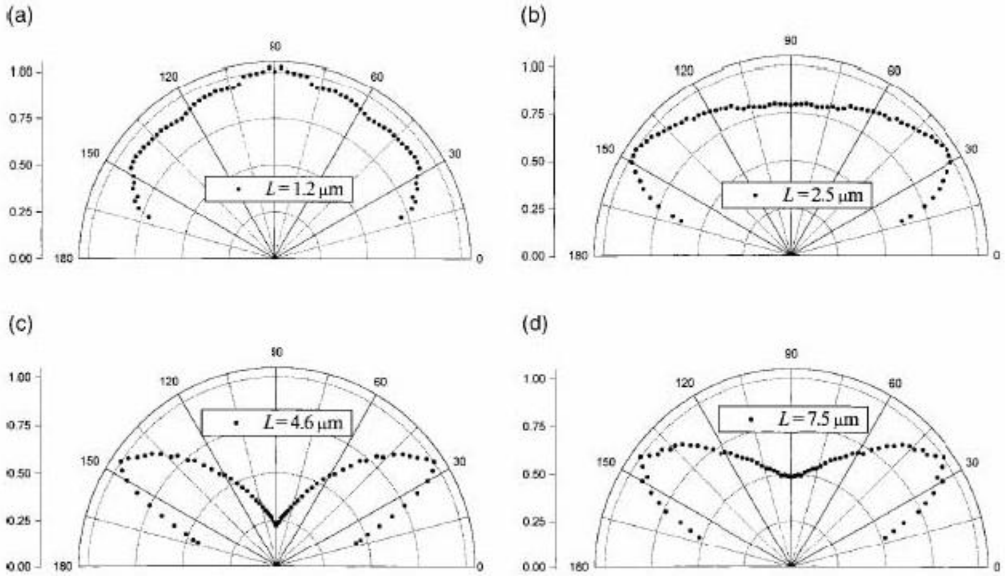
The antennas are intrinsically polarization sensitive elements. Due to the losses induced in the metallic structure, the behavior of metals at optical frequency limits the tuneability of optical antennas. This capability may compromise fine tuning of the antennas. However, this problem may be overcomed by some

electromechanical layouts which can produce a reasonable tunning of the devices. In figure 2 polarization sensitivity is being shown.



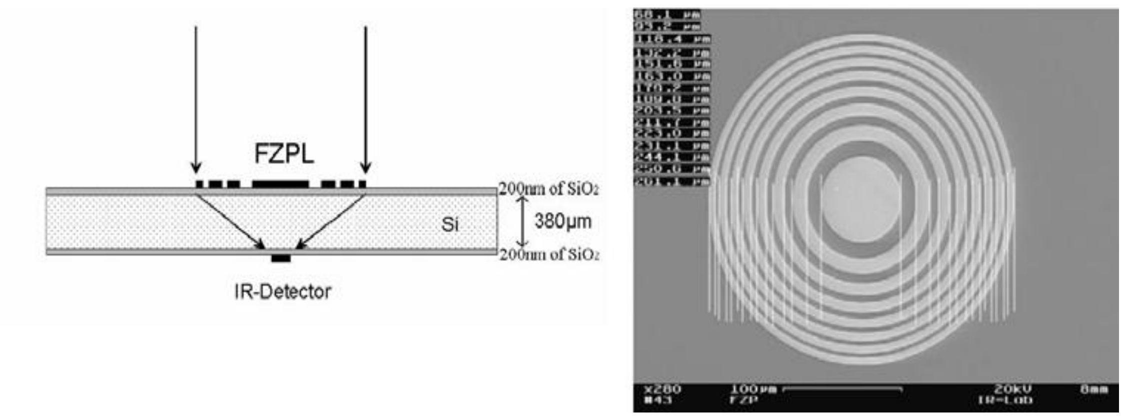
IV. Directional Sensitivity

Antennas are direction selective elements per se. This property is strongly dependent on the geometry of the antenna. In figure 3 the results obtained for several dipole antennas by changing the dipole length are shown



DETECTION SENSITIVITY

T In figure 4 the use of Fresnel zone plates specifically designed to improve the responsivity of the optical antenna is provided. Here the Fresnel zone plate is fabricated to make possible a gain in the responsivity.



Experimental set-up

V. Applications

Optical antennas will find its application niche in those areas where their outstanding characteristics in polarization sensitivity and point-like footprint are preferred and appreciated. The most interesting characteristics of optical antennas are: their point-like character (actually, they could be considered as the optical detectors having the minimum size); their polarization sensitivity; the broad-band response in wavelength; the fast time of response when using metal-oxide-metal (MOM); their integrability with read-out electronics, and diffractive optics; and their natural operation at room temperature. Among those characteristics that need to be optimized we may find their low responsivity, the attenuation due to thermal effects, the aging of the devices, and their sensibility to electric static discharges. We can solve most of these problems by an appropriate change in the design and fabrication protocols.

As an application of optical nano-antenna, a single palladium nano particle can be placed in the focus of a nano-antenna made of gold. The interaction between the gold and the palladium nano particle creates a light wave surface plasmon radiation so that any particle that is brought near the vicinity changes the dielectric function of the palladium particle as it absorbs or releases it. Light scattered by the system can be collected by a dark-field microscope and the change read out in real time. The antenna enhancement effect can be controlled by changing the distance between the palladium nano particle and the gold antenna. The shape of the nano-antenna is important too, so that antennas that form a pointed tip are especially good for plasmonic sensing. This device could be used to detect flammable gases, like hydrogen, that might easily be ignited by electricity during measurements with conventional sensors. Detecting small amounts of hydrogen is becoming increasingly important for developing fuel cells, especially as the gas can explode or ignite at concentrations of as little as 4%.

Another important application of nano-antenna is in the field of biochemistry. It can be used to pick up very small changes in a nano particle which may be optimised for specific chemicals. This is an important step in plasmonic bio-sensing with many possible applications. The new device can provide a general blueprint for amplifying plasmonic sensing signals using single particle that may pave the road for optically observing chemical reactions and catalytic activities in nano reactors. It offers a unique tool for probing biochemical processes using light.

VI. Conclusions

In this paper we have made a brief presentation of optical antennas. The same type of fundamental mechanism is used that one already proved by the radio electric antennas. The metallic structures of optical antennas couple the electromagnetic radiation and excite electric currents that are rectified and converted into a manageable signal by a transducer element located at the feed point of the antenna. Optical antennas can be shaped in a great variety of forms and configurations, sometimes mimicking their radio electric counterparts, and some other times generating new designs and elements able to enhance the appealing properties of the optical antennas.

We may conclude that optical antennas represent a portion of light detection area where technologic and fundamental problems need to be taken into account simultaneously. The research on this topic will benefit from advances in the precise knowledge of the interaction between electromagnetic radiation and matter, and also on the expertise in the design, fabrication and testing of the manufactured devices.

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